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Mathematical Model of Management of Interactive Services in Information Systems

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Abstract - In modern society, information technologies are developing rapidly, which requires new interactive services in various fields, in particular, information systems. Development of mathematical models is important for effective management of such services. In this article, we study the processes of developing mathematical models of interactive service management in information systems and their implementation. Interactive services are services that allow interaction with users. Thanks to these services, users receive information faster, which speeds up their decision-making process. Therefore, it is important to manage services more efficiently and quickly through mathematical models in this area. The article also considers the main difficulties and problems related to the management of interactive services in information systems, the role and importance of mathematical models in solving these problems. Our goal is to offer new approaches and methods for more effective management of interactive services in information systems.

1. INTRODUCTION

Through this study, we will try to develop a mathematical model of interactive service management in information systems and determine ways to improve its effectiveness. This is of great importance not only technologically, but also economically, because through this we will be able to optimize business processes and provide better service to users.

Normative recommendation documents on the introduction of interactive services in information systems have been developed. It is necessary to form various statistical data in the form of reports in the specified forms in the activity of exchange of resources within the framework of interactive services in the information system of organizations.

2. MATHEMATICS

Statistical data of interactive services, in particular, in the conditions of information systems or databases, there is a need to solve the issue of managing, evaluating and decision-making, the possibility of forming information related to the required analysis[1].

Let the formed data set be expressed in the following form:

$$D = \{D_i\}, i = 1, \ldots, n$$

here, D_i– statistics of the type of interactive service in question. n -is the number of statistics.

Each statistic has a specific data structure:

$$\begin{cases} D_1 = \{d_{11}, d_{12}, \cdots, d_{1m_1}\} \\ D_2 = \{d_{21}, d_{22}, \cdots, d_{2m_2}\} \\ D_3 = \{d_{31}, d_{32}, \cdots, d_{3m_3}\} \\ \vdots \\ D_N = \{d_{N1}, d_{N2}, \cdots, d_{Nm_N}\} \end{cases} \qquad (1)$$

In general, $D_i = \{d_{ij}\}$, $i = \overline{1, N}$, $j = \overline{1, m_\iota}$, where d_{ij} is the j-statistical attribute (meta-data) of the i-reference.In turn, certain limits and data ranges can be defined for each statistical data attribute. The appearance of the constraint depends on the type of the statistical data attribute, that is, whether it is expressed as a scalar or vector variable.

With the statistics attribute as a scalar variable, let this constraint take the following form:

$$d_{ij} \in D_{ij} , i = \overline{1, N} , j = \overline{1, m_\iota}$$

in this D_{ij}=$\{\mu_{ij} \cdot \gamma_{ij}\}$, μ_{ij}– j-statistic attribute value range, γ_{ij}=$\{0;1\}$.

When the statistical data attribute comes as a vector variable -$d_{ij} = \{d_{ij}^1, d_{ij}^2, \ldots, d_{ij}^l$ and the above restrictions take the following form:

$$d_{ij}^k \in D_{ij}^k, i = \overline{1, N} , j = \overline{1, m_\iota},\ k = \overline{1, l} . \qquad (2)$$

In this case $D_{ij}^k = \{\mu_{ij}^k \times \gamma_{ij}^k\}, \mu_{ij}^k, -j$ –the range of values of the k-component of the statistical data attribute, γ_{ij}^k=$\{0;1\}$.

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Then, the set of optional interactive service statistics attributes can be expressed as follows

$$D_o = \{d_1^0, d_2^0, \ldots, d_n^0\} \quad (3)$$

here, d_j^0 – j- statistical information attribute for the subject area under consideration.

In turn, $\bigcup_{i=1}^{N} \bigcup_{j=1}^{m_i} d_{ij} \subset D^0$ it follows.

Each statistic attribute - the values it accepts - d_j^0 also has a certain range of values.In general, the restrictions imposed on statistical data attributes can be expressed as follows:

$$d_j^0 \in D_j^0, j = \overline{1,n} \quad (4)$$

here $D_j^0 = \{\mu_j^0 \times \gamma_j^0\}, \mu_j^0$,–j-statistics attribute range of values, γ_j^0={0;1}.

Let the summary of statistical data attributes for the set of used references be organized as expression (4).

If $d_{ij} \equiv d_{kl}$ and the constraints for them also take the form $D_{ij} \equiv D_{kl}$, then removing one of the statistical attributes d_{ij} or d_{kl} from the set D ensures that the set is sufficient for the valid applications. As a result, a new set of statistical information attributes of applicants is generated:

$$X = \{x_1, x_2, \ldots, x_n\},$$

In this case, $x_i \in D_0$ and $\exists d_{ij} \in D$, $x_i \equiv d_{ij}$, $x_i \in (X_i \equiv (D_{ij} = \{\mu_{ij} \cdot \gamma_{ij}\}))$, $x_i \cap x_j = 0$, $i \neq j$. X–A range field is a class of statistical data attributes that need not be different, x_i, x_j attributes do not intersect. In this casei- the set of constraints defined for the attribute is represented by Xi and It is defined as $X_i = \{\mu_{ij} \times \gamma_{ij}\}$. The elements of this set consist of the content of the i-information attribute mi and a numerical value gi representing its length, and each set of references X_i has its own statistics, that is, it consists of attributes:

$$x_i = \{x_i^1, x_i^2, \ldots, x_i^n\} ,$$

in this x_j^i-i- the attribute of the document has its own content and size, i.e $x_j^i = (t_i^j, l_i^j)$, t_i^j- content, l_i^j- is its numerical value.

The structure of intellectual service appeal in information systems should be expressed as follows:

$$W = \{w_1, w_2, \ldots, w_k\} ,$$

here, $w_1, w_2, \ldots, w_k$– required statistical data attributes.

There are certain limits to the values you can receive per w_k:

$$w_1 \in W_1 , w_2 \in W_2, \ldots, w_k \in W_k.$$

To formalize the minimal set of electronic reference statistical data attributes, an n-dimensional l-vector is introduced and it is:

$$\lambda = \{\lambda_i\}, i=1,\ldots,n, \lambda_i \in \{0,1\}.$$

The expression $LW = \{l_1 w_1, l_2 w_2, \ldots, l_{nwn}\}$ is considered appropriate for an arbitrary electronic reference W. In this case, if $l_i = 0$, then it is known that the i-th attribute is not present in the reference W, otherwise, i.e., if l_i=1, this attribute is present.

It follows that the composition of statistical data attributes of the considered application is coordinated with the minimally sufficient set of statistical data attributes of the application using the vector λ. In this,condition is also taken into account:

$$w_i \in \bigcup_{j=1}^{n} X_j , i \in \{1, \ldots, K\}$$

If $w_i \in \bigcup_{j=1}^{n} X_j$, then the i-statistical attribute of the requested request has value g_i defined in interval m_j.

Formalization of the attributes of statistical data in the interactive system, as well as information on the attributes of statistical data for the activity of information systems intended for the organization's document circulation in exchange for words to the information system. Such information systems are considered convenient for the purposes of quick and timely response to various requests.

Special pre-prepared templates are used to submit requests for requests that have become commonplace in electronic document circulation.Based on the analysis of associative relationships of statistical data, it is required to develop samples of appeals with a high probability of being asked. Let such a set of appeals be expressed in the following form:

$$A = \{A_1, A_2, \ldots A_N\} ,$$

In this, $A_1, A_2, \ldots A_N$– statistics of the type of interactive service in question.

Each of the references has a certain data structure, for example:

$A_i = \{a_{ij}\}, i = \overline{1,N}, j = \overline{1,m_\iota}$, where aij is the j-statistical attribute of the i-reference. If this is expressed as a set of statistical attributes $O = \{w_1, w_2, \ldots, w_{1k}\}$, statistical data attributes of prepared applications $\forall a_{ij}\ i = \overline{1,N}, j = \overline{1,m_\iota}$, O will apply to the set $d_{ij} \subseteq O$.

In addition, it is enough to determine the interrelationships of the $O = \{w_1, w_2, \ldots, w_k\}$ set attributes to prepare the required extimal reference templates.

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We assume that the following attribute selections can be generated without considering the sequence of $O = \{w_1, w_2, \ldots, w_k\}$ set attributes:

1st element selections:: $\{w_1\}$, $\{w_2\}$, $\{w_3\}$, …, $\{w_N\}$.

2nd-element selections: $\{w_1, w_2\}$, $\{w_1, w_3\}$, …, $\{w_1, w_N\}$, … $\{w_{N-1}, w_N\}$.

…

Nth-elemental single selection: $\{w_1, w_2, \ldots, w_N\}$.

Then the total number of such selections for the attributes of the set O in question is

$$m_c = \sum_{i=1}^{N} C_N^i \, (C_N^i = \frac{N!}{i! * (N-1)!}, \forall i, i = \overline{1, N})$$

It does not make sense to look at single-item selections to determine attribute correlations. Therefore, the selections that can be made are expressed in the following form:

$$A = \{a_i\}, i = 1, \ldots, n\},$$

Here

$$n = \sum_{i=2}^{N} C_N^I, a_j \subseteq O. (5)$$

Each element of this set A appears in a certain number of references to set D. Let this quantity be expressed in the form of Supp(aj) and be called the power of aj and be calculated based on the following formula:

$$Supp(a_j) = \frac{|D_{a_j}|}{|D|} (6)$$

Here $\forall_{a_j} j = \overline{1, m}, Supp(a_j) \in [0; 1]$.

As a result of sorting the elements of set A based on this parameter, the following set V is formed:

$B = \{b_j\}, j = \overline{1, m}, Supp(b_k) \geq Supp(b_i)$,here$k < l, \forall k, l \in \{1, 2, \ldots m\}$.

Analysis of the subsets of statistical data attributes corresponding to the elements of the V set presents their degree of dependence. It can be noted that the set $\{w_1, w_2, \ldots, w_N\}$ of statistical data attributes can be relatively important.

In the framework of interactive services through information systems, a large number of applications related to various activities are received, and in some cases, incorrect information is received. An analysis of the data circulating within the interactive services system reveals that the available data is incomplete, inconclusive, and that much of the data is out of date and difficult to justify.

One of the main ways to overcome such situations is to increase the accuracy and reliability of decisions to a certain extent by applying a decision-making model in the management of intelligent systems.

The widespread use of mathematical modeling in the management of interactive services is mainly effective in solving problems of predicting interactivity in advance[1]. The achievement of the model is that it serves as a convenient tool for learning by analyzing the specific characteristics of the management system. This, in turn, makes it possible to evaluate the activities of managing interactive services in different conditions, analyze their possible situations, and choose the most effective among the available actions.

In practice, it is possible to quickly and reliably determine the effective management decisions selected by conducting real experiments, the effective management decisions in the values of the parameters of the computer-generated model in the specified range[2].

Modeling can be built on the basis of two directions, that is, by studying the state of interactivity, its systematic change from a dynamic point of view, and the characteristics and phenomena of managing the activity of interactive services.

When constructing a mathematical model of the characteristics and phenomena of the management of interactive services, it is necessary to take into account the quantitative interrelationships of various factors, including: economic, demographic, geographical, political, interactive situations. Based on the collected values for each studied factor, models representing the studied phenomenon or feature are built.

The widely used models in the management of interactive services are correlational and regression models, with the help of which the interrelationships between social events are expressed through probability levels. Models of this type first found their practical application in solving various problems.

The relationship created in the management of interactive services should be represented by a one-factor linear model:

$$x = a_0 + a^* \cdot X + E, \quad (7)$$

here x - number of appeals in one year; X - the number of inhabitants (province, city, district) corresponding to this year (thousands of people);a^* −the effect of population size on the number of referrals to interactive services; a_0, E - characteristics representing the influence of various factors.

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In the analysis of the management of interactive services, taking into account the fact that interactivity changes dynamically over time, and the growth of applications depends on the interaction of the population flow, which is also characterized by the fact that the population belongs to different categories.

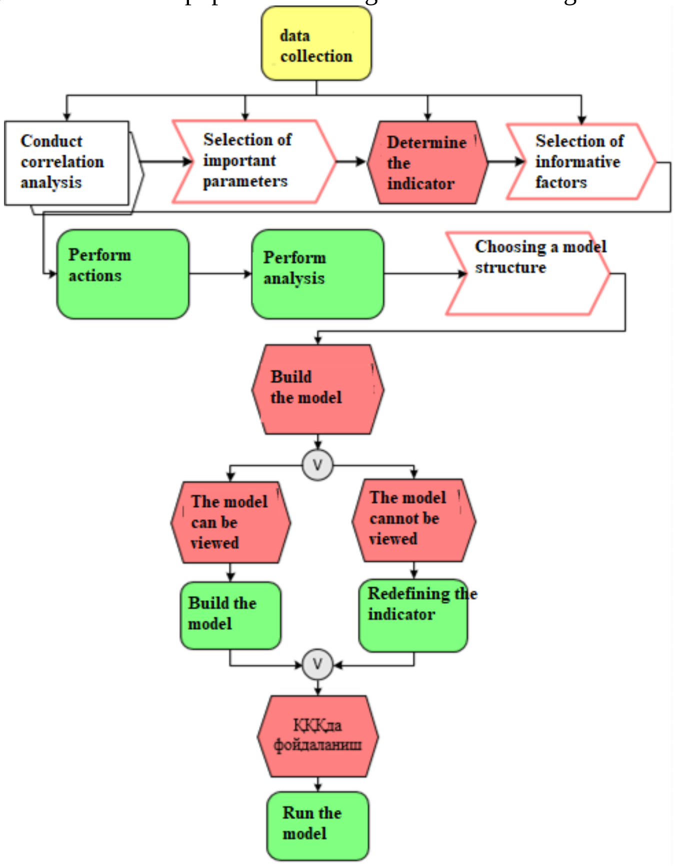

Figure 1. Building a decision-making model.

In general, when building a dynamic model of interactive service management, six groups of elements are considered, which move from one category to another. To them, applicants N(t), N(T), unfinished applications X(t), completed applications Y(t), active applications Z(t), previously unimplemented applications S(t) and previously implemented applications R(t). The number of applications included in repeated applications depends on the efficiency of the interactive services staff and is represented by the function EE.of the interactive services staff and is represented by the function V(t).

In a simplified case, the system of equations of the dynamic model takes the following form.

$$\begin{aligned}
&N(t) = M(t) - X(t) - Y(t) - Z(t) - S(t) - R(t),\\
&X(t+1) = x(t) + \alpha \cdot X(t) + \mu \cdot R(t) \cdot X(t) - V(t),\\
&Y(t+1) = Y(t) + V(t) - \gamma_1 \cdot Y(t) - \gamma_2 \cdot Y(t) - \gamma_3 \cdot Y(t),\\
&Z(t+1) = Z(t) + \gamma_1 \cdot Y(t) - \eta_1 \cdot Z(t) - \eta_2 \cdot Z(t),\\
&S(t+1) = S(t) + \gamma_2 \cdot Y(t) - \eta_2 \cdot Z(t) - \nu \cdot S(t),\\
&R(t+1) = R(t) + \gamma_3 \cdot Y(t) + \eta_1 \cdot Z(t) + \nu \cdot S(t) - \mu \cdot R(t) \cdot X(t)
\end{aligned} \tag{8}$$

herecoefficients: $\alpha, \mu, \gamma_1, \gamma_2, \gamma_3, \eta_1, \eta_{2,} \upsilon$

α- the previously given coefficient, the ratio of the number of unsolicited appeals to the number of all appeals;

μ- pre-given coefficient, the ratio of the number of pre-used references to the total number of references;

γ_1- the coefficient that characterizes the transfer of identified appeals to the active category;

γ_2- number of user referrals that do not require defined referrals;

γ_3- the ratio of the number of references to the total number of references that fall into the identified previously used, indifferent category;

η_1 – the number of appeals that have already been made in the desired category;

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$\eta_{2,}$- the number of appeals that have already been implemented and are in the category of unwillingness to implement the appeal;

υ- the coefficient determines the transition from the previously implemented, unwilling to implement category to the willing to implement category;

M(t) -the number of people who are inclined to apply (from 14 to 60 years old).

The proposed model (8) can be widely used to represent various interactive services when improved. On the basis of this, the expression of changes in territorial appeals from a dynamic point of view is carried out. The unique feature of the model is that it includes not only the application process, but also demographic aspects and territorial migration of the population.

When creating a model, the state of interactivity in each region should be studied separately.

In the construction of a mathematical model, parameters with significance were selected by correlation analysis and experts' conclusions. The models were mainly created in relation to the employees of the IX of state bodies, the total number of appeals recorded during the year, the population of the region, and the area of the region.

Standard software tools that are available and widely used in practice can be used to create a model. The method of least squares was used in statistical data processing[2].

The accuracy of the created model is checked using Fisher's criterion[3].

$$F = \frac{S_{a\partial}^2}{S_y^2} \le F(0.05; f_{a\partial}; f_y). \tag{9}$$

here$S_{\alpha\delta}$ - the dispersion accuracy of the model is calculated and it is defined as follows:

$$S_{a\partial} = \frac{\sum_{i=1}^{n}(y_i - y_i^*)^2}{n-m-1}; \tag{10}$$

here$y_i - i -$is the calculated value of the resulting parameter;

$F(0,02; f_{\alpha\delta}, f_y)$ - Fisher's criterion at the 2% value,

$f_{\alpha\delta} - (m-1)$- number of degrees of freedom of precision variance;

n - the number of observations collected by year;

m – the number of parameters used in model construction.

The analysis of the obtained results showed that in all cases the value obtained from the calculation result is smaller than F_{jadv} in the standard table F_{hisob}, that is $F_{hisob} \le F(0,02; f_{\alpha\delta}; f_y$. This mathematical model fully represents the process of managing interactive services.

Using the Student criterion of mathematical statistics, the significance of the coefficients determined in the process of building the model is characterized by the fulfillment of the following inequality

$|b_i| \ge b_i$,in this caseThe reliability interval of the coefficients in the $\rhd b_i -$ model is calculated and determined as follows

$$\rhd b_i - t(0,02, f_k)\sqrt{\frac{S_{h_i}}{n}}, \tag{11}$$

here$S_{b_i} = S_y^2/f_n$ - exclusion of regression models;

$t(0,02; f_k)$- 2 percent $f_k = m - 1$ free index distributed Student Node.

3. CONCLUSION

In this article, mathematical models developed for managing interactive services in information systems were discussed. During the research, we looked at the different types of interactive services and their characteristics, as well as the main challenges faced in managing them. In this, the important role of mathematical models in improving the efficiency of service management was emphasized.

As noted in the article, interactive services can be managed more effectively with the help of mathematical models. Through these models, the speed, reliability and flexibility of services are increased, which in turn allows to provide high quality service to users. At the same time, with the help of these models, it is possible to optimize services and allocate resources efficiently.

Future research should focus on further improving mathematical models in this area. In particular, it is possible to develop new methods of managing interactive services by applying artificial intelligence and big data processing technologies. It is also important to develop specific models adapted to different industries, including finance, health, and education.

In conclusion, the use of mathematical models in the management of interactive services plays an important role in making information systems more efficient and user-friendly. Future research will help to further develop this field and open up new opportunities.

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